

## **CHAPTER 9. SHIPMENTS**

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## CHAPTER 9: SHIPMENTS

### 9.1 INTRODUCTION

Estimates of future energy consumption of furnaces and boilers rely on an accurate estimate of the future shipments of heating equipment for each product class. To provide such estimates, the Department constructed a shipments forecasting model that accounts for equipment shipped to new homes, equipment used to replace existing units, and equipment installed during the process of converting to a different heating fuel. This chapter describes the shipments model and presents the forecasts of future shipments in each product class.

Chapter 3: Market and Technology Assessment, shows past trends in shipments of each product class. Shipments are increasing in general because the number of houses is increasing, more equipment is reaching retirement age, and the saturation of central heating in new homes is increasing. The short-term peaks and dips in shipments arise from variations in housing construction.

Furnace and boiler shipments are in response to: (1) replacements of retired units with the same type (“in-kind replacements”), (2) conversions at retirement to another fuel type, and (3) installations in new homes. Almost all new construction has central heating equipment, and nearly all equipment is replaced upon retirement.

$$Shipments_{y,class} = Replacements_{In-Kind,y,class} + Conversions_{y,class} + NewHousing_{y,class}$$

where:

$Shipments_{y,class}$	=	total shipment per product class,
$Replacements_{In}$	=	replacements of retired equipment with the same type equipment (“in-kind replacements”)
$Conversions_{y,class}$	=	equipment conversions at retirement to another fuel type
$NewHousing_{y,class}$	=	equipment installations in new homes.

The Department estimated the number of replacements based on past shipments and expected retirement rates. Forecasting future replacements requires estimates of shipments to new housing, since replacements 20–30 years from now will replace equipment shipped in the next few years. Consumers most commonly replace equipment with equipment in the same product class. Some fraction of households switch fuels, retiring an oil or electric unit and replacing it with a gas system (conversion from natural gas to other fuels is rare). The Department estimated future conversions based on historical data.

The Department estimated the total number of shipments to new housing based on projections of new housing construction. Market shares of heating equipment in newly constructed homes reflect a choice that is influenced by fuel costs and equipment prices. For

non-weatherized gas furnaces and mobile home furnaces, the Department modeled this choice using equipment price and fuel price as independent variables.

The Department estimated annual shipments from 2003 through 2035, which is the end year used in the current rulemaking.

## 9.2 REPLACEMENTS AND CONVERSIONS

Historical shipments influence the number of replacement units of each product class entering the housing stock in each year. The replacements model estimates what fraction of the historically shipped units are still in service, and how many will be replaced each year. The replacement model uses estimates of how long each type of equipment is expected to operate before it is replaced. Depending on the age (vintage) of a piece of heating equipment, there is a certain probability of its being replaced. The model uses a replacement probability distribution based on minimum, mean, and maximum expected equipment lifetimes (Table 9.2.1). For all products except boilers, the lifetimes are from *Appliance Magazine*.<sup>1</sup> For boilers, the lifetimes are from a Gas Research Institute (GRI) report.<sup>2</sup>

**Table 9.2.1 Expected Equipment Lifetime (years)**

	<b>Gas Furnace</b>	<b>Oil-Fired Furnace</b>	<b>Gas Boiler</b>	<b>Oil-Fired Boiler</b>	<b>Heat Pump</b>	<b>Electric Furnace</b>
Min	10	10	13	12	6	11
Mean	20	15	17	15	14	17
Max	30	20	22	19	21	23

Two basic assumptions influence the probability distribution. First, the Department expects equipment to have a maximum probability of being replaced at the mean lifetime. Second, replacement probability goes to zero in the minimum and maximum lifetime years. Assuming a linear slope in probability produces a triangular distribution.

Given the probability of replacement as a function of equipment vintage, the calculation of expected replacements in any given year follows directly from past shipments. In a given year, the number of replacements is equal to the portion of the previous year's shipments expected to retire, plus the number of shipments from other past years expected to retire.

The above calculation yields total replacements in a given year. The majority are replacements in kind—consumers replace existing equipment with equipment of the same product class.

### 9.2.1 Conversions

To estimate future conversions, DOE uses data from the annual house heating survey conducted by the American Gas Association (AGA).<sup>3</sup> On average, about 100,000 oil-heating households and 75,000 electricity-heating households annually converted to natural gas in that period. The number of conversions from gas to oil or electricity is negligible.

The conversion rate is the fraction of oil or electric equipment retirements in which the consumer decides to change to gas heating. In the 1990-1995 period, nearly a third of oil-heating customers and more than a quarter of electric-heating customers decided to convert to natural gas instead of replacing their old system with the same fuel type.

Conversion from electric and oil heat to gas heating is driven primarily by consumers' perception of operating cost advantages. Given that DOE expects gas heating to continue to have advantages in this regard, it assumed that the conversion rates estimated from the AGA data—33 percent for oil equipment (furnaces and boilers) and 26 percent for electric heating equipment—will continue in the future. Changes in equipment cost of gas furnaces due to possible standards are not likely to have a significant impact on the conversion rates. Since the oil-fired furnace and boiler markets are mostly replacements, oil-to-gas conversions will have a significant negative impact on shipments of these product classes in the future.

**Table 9.2.2 Conversions to Natural Gas From Oil and Electric Heating**

	Conversions to Natural Gas from (Thousands):		Estimated Replacements (Thousands):		Fraction of Replacements	
	Oil	Electricity	Oil	Electricity	Oil	Electricity
1990	118	57	360	256	32.8	22.3
1991	122	68	345	281	35.3	24.2
1992	125	96	324	289	38.6	33.2
1993	95	107	294	293	32.4	36.5
1994	73	58	254	289	28.7	20.1
1995	52	57	217	282	24.0	20.2
Total	585	443	1793	1690	32.6	26.2

Source: AGA House Heating Survey<sup>3</sup>

## 9.2.2 Replacement and Conversion Estimates for 2000

Using historical shipments data and the conversion rates mentioned above, DOE estimated shipments for replacements and conversions in year 2000 (Table 9.2.3).

**Table 9.2.3 Replacement and Conversion Estimates for 2000**

	<b>Gas Furnaces</b>	<b>Oil-Fired Furnaces</b>	<b>Gas Boilers</b>	<b>Oil-Fired Boilers</b>
Estimated Replacements (thousands)	1,452	160	179	103
Estimated Conversions (thousands)	132	-52	34	-34
Replacement plus Conversion (thousands)	1,584	108	213	69
Shipments (thousands)	3,100	121	212	162

## 9.3 SHIPMENTS TO NEW HOUSING

Approximately 95 percent of new housing units built today have central heating using a furnace, boiler, or heat pump. A small and declining number of new housing units rely on other forms of heating, such as wall units or space heaters. The Department assumed an annual growth rate of the central heating market share (including furnaces, boilers, and heat pumps) of 0.47 percent, calculated from the trend in 1994-1999. The projected share of central heating approaches 100 percent of new housing units by 2012.

Gas furnaces were installed in nearly 60 percent of homes built between 1995 and 1999, according to the U.S. Census Bureau's *American Housing Survey*.<sup>4</sup> Electric central heating systems (including heat pumps) accounted for about 30 percent of the systems installed. Oil-fired furnaces and gas- or oil-fired boiler systems, combined, appeared in only about 5 percent of new homes.

The new housing market for furnaces is the component of the forecasted shipments DOE expects to be most sensitive to economic factors, for two reasons. First, housing construction is closely tied to economic growth—dips and peaks in historical shipments of heating equipment tend to follow national economic trends. Second, DOE expects changes in equipment cost or operating expense associated with a particular product class to affect relative market shares in new construction much more significantly than in the replacement market. Market share data (presented below) suggest that changes in first cost and operating cost have had an effect in the past on the choice of installing either a gas furnace or an electric central heating system in a new home.

### 9.3.1 Approach

In the Department's method, the number of annual shipments of each product class going to new housing units is equal to housing completions for that year, multiplied by the market share held by each product class. For non-weatherized gas furnaces and mobile home gas furnaces, the shipments model takes into account possible market-shift effects from changes in equipment prices related to efficiency standards.<sup>a</sup> The Department estimated future market shares using historical relationships between gas and electricity prices, gas and electric heating equipment prices, and gas furnace market shares, combined with estimated increases in installed equipment cost associated with higher efficiency. For the other product classes, DOE assumed that current market shares remain constant in the future.

### 9.3.2 New Housing Projections

New housing includes single- and multi-family units, referred to as "new housing completions," and mobile home placements. For new housing completions and mobile home placements, DOE used actual data through 2001, and adopted the projections from EIA's *Annual Energy Outlook 2002 (AEO2002)* for the 2002–2020 period.<sup>5</sup> This forecast shows some increase in housing completions to about 1.6 million by 2012, and to 1.7 million by 2020. The Department assumed that completions grow at 0.5 percent per year (the projected average annual growth rate in the 2000–2020 period) for the 2021–2035 period. For mobile homes, DOE extrapolated the trend of constant placements flat growth in 2010–2020 out to 2035.

### 9.3.3 Heating Equipment Market Share in New Housing

The Department modeled market shifts between gas furnaces and electric central heating in new housing. For a given heating load, gas furnaces are less expensive to operate than electric heating equipment, and forecasts of fuel prices predict that this will continue to be the case. Therefore, the Department does not expect a large shift from gas to electric heating due to increased costs of gas-fired equipment.

The forecast of gas and electric market shares in new housing follows an econometric approach. For the years 2000–2011, the model predicts changes in market share relative to 1999 produced by proportional changes in gas and electricity prices.<sup>b</sup> The 1999 shares are taken from U.S. Census construction data.<sup>6</sup> For 2012 and after, the model predicts changes in market share produced by shifts in equipment prices due to standards, as well as shifts in energy prices.

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<sup>a</sup> DOE believes that there would be little if any market shift away from gas for weatherized gas furnaces. There are very few packaged units with electric resistance heating, and there is no data to suggest any trend change. Thus, it is unlikely that their fraction would increase in connection with efficiency standards for weatherized gas furnaces.

<sup>b</sup> DOE used 1999 as the base year in order to avoid the fluctuation in natural gas prices in 2000–2001.

To estimate the degree to which an increase in gas furnace equipment cost will induce a shift in the market toward electric heating, the market share model uses historical trends in national-average gas and electricity prices<sup>7</sup> and heating equipment prices.<sup>8,9</sup> It also uses data on the gas furnace market share in each group.<sup>10</sup> These data indicate consumer/builder equipment preference and its dependence on first cost and operating expense.

In colder regions, electric heating is prohibitively expensive. In the Southern census region and in mobile homes, however, operating cost is less of a factor relative to the first cost of equipment. Purchasers of mobile housing often have lower incomes and therefore may be more sensitive to first costs than other households. For these reasons, DOE independently estimated market shifts for three groups: single-family and multi-family (SF+MF) homes in regions other than the Southern census region, SF+MF homes within the Southern census region, and mobile homes in all census regions.

In new homes that are not mobile homes, heat pumps are the main competitor to gas furnaces, and the increasing market share of heat pumps has been influenced by declining equipment costs. The Department used retail price data on residential central air conditioners<sup>11, 12</sup> as a proxy for retail heat pump prices. While the cost of gas furnaces has declined over the years, the price of air-conditioning equipment has dropped more dramatically.

The market share of gas furnaces in each group is given by:

$$MS_y = MS_0 \times \left[ 1 + \varepsilon_F \left( \frac{\Delta F}{F_0} \right)_y + \varepsilon_E \left( \frac{\Delta E}{E_0} \right)_y \right]$$

where:

- $MS_0$  = market share in the reference year,
- $F$  = an index (ratio) of gas-to-electricity price,
- $E$  = an index of gas-to-electric equipment price, and
- $\varepsilon_F$  and  $\varepsilon_E$  = “elasticities” that measure the change in market share that occurred in response to changes in the gas-to-electric price ratio and the gas-to-electric installed equipment price ratio.

The terms  $\Delta F/F_0$  and  $\Delta E/E_0$  are percentage increases in prices in a given year relative to the reference period, which is 1960–1969. Table 9.3.1 summarizes the data for the regions.

**Table 9.3.1 Change in Energy and Equipment Price Indices and Gas Furnace Market Share in New Housing**

Year	Change in Gas/electric Energy Price Ratio, Relative to 1960-69 Average	Change in Gas/electric Equipment Price Ratio, Relative to 1960-69 Average	Gas Furnace Market Share		
			SF + MF - Outside South	SF + MF - South Only	Mobile Homes - All Regions
1960-1969			91.4%	61.5%	59.7%
1970-1974	0.025	0.086	85.1%	47.2%	49.8%
1975-1978	0.129	0.123	74.0%	37.0%	36.7%
1979	0.388	0.087	74.2%	29.1%	35.7%
1980	0.432	0.089	74.4%	26.6%	35.6%
1981	0.419	0.195	73.1%	31.8%	23.0%
1982	0.548	0.262	76.2%	28.0%	34.5%
1983	0.749	0.305	74.3%	27.0%	27.7%
1984	0.655	0.323	67.1%	28.7%	30.5%
1985	0.590	0.354	71.1%	25.8%	27.4%
1986	0.492	0.389	75.9%	36.6%	56.0%
1987	0.428	0.378	74.6%	29.2%	44.7%
1988	0.400	0.378	78.4%	26.5%	75.0%
1989	0.398	0.371	80.3%	33.4%	33.6%
1990	0.369	0.450	80.7%	28.2%	36.7%
1991	0.336	0.466	76.4%	31.1%	36.8%
1992	0.334	0.545	79.5%	33.3%	56.7%
1993	0.389	0.574	78.6%	33.3%	70.9%
1994	0.412	0.585	83.0%	39.1%	24.6%
1995	0.312	0.551	81.2%	38.1%	83.4%

For each group, the data allow a statistical determination of the elasticities. The elasticities are negative (see Table 9.3.2), since an increase in costs associated with gas furnaces tends to lower their market share by a small amount. As expected, Southern households yield a more negative response to change in the equipment price index than non-Southern households. In both cases, however, gas market shares are more affected by operating cost—i.e., the dramatic increase in natural gas prices during the 1970s and 1980s.



**Table 9.3.2 Estimated Elasticity of Gas Furnace Market Share in New Housing in Response to Change in Fuel and Equipment Price Indices**

South Region		Regions Outside South		Mobile Homes	
Fuel	Equipment	Fuel	Equipment	Fuel	Equipment
-0.83	-0.37	-0.38	-0.02	-0.95	-0.53

Given the historic relationship between gas furnace market share and change in the gas-to-electric price, the Department expects gas furnace shares to fall slightly by 2012 due to an increase in the ratio of natural gas to electricity price. The Department expects the relationship between gas and electricity prices to be relatively stable in the period after implementation of the standard. Therefore, the Department expects no market share shifts due to changes in these prices.

The Department uses the above elasticities to estimate market share shifts due to equipment price increases associated with higher efficiency. In the South, for example, an efficiency level that raises the gas furnace installed cost by 10 percent causes a projected gas furnace market share change, in relative terms, of 10 percent x -0.37 = -3.7 percent.

The Department based the estimate of future market share shifts on the equipment and installation costs estimated in the engineering analysis (Chapter 6). The Department assumed that all shipments will incur the equipment price increase after the date of the standards implementation, but that prices will not further rise or decline over time in real terms.

The model estimates the combined market share of non-weatherized and weatherized gas furnaces in new housing completions in the South and non-South regions based on the historical parameters and their projected values. The Department estimated the shipments of non-weatherized gas furnaces alone by applying their estimated current share (88 percent) of the combined shipments. Table 9.3.3 shows that the higher equipment prices associated with higher efficiency have very little effect on the share of gas furnaces in total new housing completions at 81 percent AFUE, but have more effect at 90 percent and 92 percent AFUE.

**Table 9.3.3 Shipments of Non-Weatherized and Weatherized Gas Furnaces to New Housing for Different Efficiency Levels**

<b>Year</b>	<b>Total Completions (million)</b>	<b>Gas Furnace Share (%)</b>	<b>Gas Furnace Shipments (million)</b>
2010	1.62	54.6	0.88
2020	1.72		
Base		54.9	0.94
80%		54.9	0.94
81%		54.7	0.94
90%		54.4	0.92
92%		53.0	0.91

For mobile home gas furnaces, DOE used an approach similar to that used for non-weatherized gas furnaces. In this case, however, the impact of higher equipment cost associated with higher efficiency is greater than the effect on non-weatherized gas furnaces (Table 9.3.4). The reason is that the estimated equipment price elasticity is higher (see Table 9.3.2).

**Table 9.3.4 Shipments of Mobile Home Gas Furnaces for Different Efficiency Levels**

<b>Year</b>	<b>Total Placements (million)</b>	<b>Gas Furnace Share (%)</b>	<b>Gas Shipments (million)</b>
2010	0.300	28.5	0.086
2020	0.280		
Base		28.6	0.080
80%		28.3	0.079
81%		27.9	0.078
82%		27.3	0.076
90%		17.6	0.049

The Department estimated the future market shares of oil-fired furnaces and gas and oil-fired boilers in total new housing completions based on the average shares in homes built in 1997–1999 (Table 9.3.5). For new homes using oil equipment, gas is generally not available, so the Department assumed that the market shares are independent of changes in equipment price due to standards implementation. Gas boilers in new homes are associated with specific types of heating systems, such as hydronic radiators or radiant floors, and substitution of alternative equipment is unlikely.

**Table 9.3.5 Projected Shipments to New Housing in Other Product Classes (million)**

Product Class	Market Share (% of new housing)	2020	2030
Oil-fired furnaces	0.7	0.012	0.013
Gas boilers	2.5	0.044	0.046
Oil-fired boilers	1.8	0.031	0.032

## 9.4 PROJECTED TOTAL SHIPMENTS

The Department calculated total shipments in each class by adding new housing shipments in each year to replacements-in-kind and conversions. Table 9.4.1 shows the projections for non-weatherized gas furnaces for the base case and higher-efficiency cases. Since shipments to new housing comprise only around a quarter of total future shipments, the impact of increased equipment costs due to higher efficiency on total shipments is small. Table 9.4.2 shows the projections for the other product classes.

**Table 9.4.1 Total Shipments of Non-Weatherized Gas Furnaces for Different Efficiency Levels (million per year)**

Year	New Housing	Replacements-in-kind	Conversions to Gas	Total
2010	0.78	1.72	0.14	2.64
2020				
Base Case	0.83	2.30	0.16	3.28
80%	0.83	2.30	0.16	3.28
81%*	0.83	2.30	0.16	3.28
90%	0.80	2.30	0.16	3.26
92%	0.76	2.30	0.16	3.21

\* The values refer to single-stage furnaces.

**Table 9.4.2 Total Shipments in Other Product Classes (million per year)**

<b>Product Class</b>	<b>2012</b>	<b>2020</b>	<b>2030</b>
Weatherized gas furnaces	0.369	0.429	0.469
Mobile home gas furnaces			
Base Case Forecast	0.082	0.080	0.075
81%	0.080	0.078	0.073
Oil-fired furnaces	0.102	0.093	0.079
Gas boilers	0.290	0.345	0.380
Oil-fired boilers	0.135	0.113	0.118

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